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DENSITY AND DIVERSITY OF BLUE GREEN ALGAE FROM THE RICE FIELDS OF GOA

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ABSTRACT
Cyanobacteria forms a large group of structurally complex and ecologically significant gram negative prokaryotes which flourish in rice fields and also known to sustain the fertility of this ecosystem. This study is aimed to characterize the abundance of cyanobacteria in various habitats of rice field areas in Goa i.e. Khazan lands, Coastal areas, Hinterlands and Mining areas for khariff and rabi seasons. A total of 16 genera and 90 species of heterocystous, non-heterocystous and unicellular BGA forms were recorded. The diversity of all the three types of algae was higher in the hinterlands as compared to the other habitats and also the diversity was more in Rabi season than khariff. The density of heterocystous forms was most abundant followed by non-heterocystous and unicellular forms respectively.

KEY WORDS: Cyanobacteria; Diversity indices; Unicellular; Heterocystous; Non- heterocystous.

INTRODUCTION

Blue green algae possess an autotrophic mode of growth like eukaryotic plant cells, metabolic system like bacteria and occupy a unique position. They possess chlorophyll 'a' and are gram negative which carry out oxygenic photosynthesis. They exhibit a great morphological diversity and their broad spectrum of physiological properties reflects their widespread distribution and tolerance to environmental stress. (Tandeau de Marsac and Howard, 1993). Interesting results are obtained from detailed studies carried out on the distribution and periodicity of BGA from various parts of India. (Venkataraman, 1975; Kolte and Goyal, 1985; Singh, 1985). Several reports have indicated a widespread distribution of forms like *Oscillatoria, Nostoc, Anabaena, Phormidium and Aphanothece* (Gupta, 1975; Sinha and Mukherjee, 1975; Paul and Santra, 1982). Singh (1950) and Talpasayi (1962) made a systematic enumeration of cyanobacteria collected from moist soils and rocks. Research has also shown the occurrence of mostly heterocystous forms due to their competitive ability in comparison to non-heterocystous forms (Garcia-Pichel and Belnap 1996). The dominating heterocystous nitrogen fixing blue green algal species of *Aluosira, Cylindrospermum, Nostoc, Anabaena, Tolypothrix* and *Calothrix* were reported from soils of Cuttack and Orissa (Singh, 1961). Distributional profiles of cyanobacterial isolates from soils of Bhubaneswar, Cuttack and Howrah indicated the predominance of heterocystous strains. (Sudhir Saxena *et al*., 2007). Paddy field ecosystem provides a unique aquatic-terrestrial habitat for the favourable growth and nitrogen fixation by cyanobacteria meeting their requirements for light, water and higher temperature thus maintaining the stable yield of rice under flooded conditions and also the productivity of soils (Roger *et al*., 1993). Goa is a coastal region with a hot, humid and tropical climate with about 54 thousand hectares of land under rice cultivation, which is the staple food of Goans (Sakshena, 2003). Rice *(Oryza sativa L),* the staple food of Goans is being cultivated over an area of 54,000 hectares both in Kharif (44,000 ha) and Rabi (10,000 ha). This cereal crop accounts for 31% of the total cropped area and 86% of the food grain production. It is cultivated on three different land types *viz.* Kher lands (rainfed lowlands), Morod lands (rain fed uplands) and Khazan lands (coastal saline lands). Our investigation was directed towards evaluating the density and diversity of BGA in four different types of rice fields in Goa which are influenced by different environmental conditions.

MATERIALS AND METHODS

The four different fields selected were:

1. Khazan lands – which are salty lands with regular influx of saline sea water and are used for rice cultivation
2. Coastal fields – which are in the vicinity of beach area
3. Mining area – rice fields which are situated close to the mines and which receive runoff and rejects of mines.
4. Hinterlands – are remote interior areas where rice cultivation is carried out and is free of coastal influence.

The physicochemical characteristics of the sampling sites were analysed with respect to their EC and pH range following the methodology outlined by Black (1992). The investigation on the density and diversity of cyanobacteria from the four selected habitats of Goa was carried out for a period of three years from June 2006 to June2009. Collection was done from the paddy fields of four habitats both in khariff and rabi seasons of rice cultivation. Collection was made in fixed spots marked for collections in a 1L capacity wide mouthed bottle. The phytoplanktons were immediately preserved in 1% lugol's iodine solution (1ml/100ml). This sedimented the phytoplankton. After all phytoplanktons settled the supernatant is siphoned out and the remaining sample is concentrated by centrifugation in a centrifuge at 1500 r.p.m. The total concentrated volume made was 100 ml. Initial studies for taxonomic identification was carried out using light binocular microscope. The algae were then identified using keys given by Desikachary (1959), Anand (1989) and Santra(1993).

For quantitative analysis the sample was analyzed by Lackey's drop method (1938) as mentioned in APHA (1985). The formula used was -

$$\text{Phytoplankton unit per litre} = \frac{n \times c}{V} \times 1000$$

Where n = number of phytoplanktons counted in 0.1ml. (1 drop of concentrate)

c = total volume of concentrate in ml

V = total volume of water filtered in litres

A colony is considered as one individual. Filament more than ¾ as one individual. Data on density is recorded in Table 2.

Statistical analyses

The data collected for three years of study period was statistically analyzed using PAST statistical package. Shannon (H), Simpson (1-D) and Margalef diversity indices were analyzed for the three types of cyanobacteria namely Heterocystous, Non-heterocystous and Unicellular during khariff and rabi seasons of paddy cultivation.

TABLE 1. Physicochemical characteristics of soil and water of the sampling area during study period

Type of substrata	Soil		Water	
Location/Parameters	EC dsm^{-1} ± SD	pH ± SD	EC dsm^{-1} ±SD	pH ± SD
Quepem hinterlands	3.5 ± 0.1	7.3 ± 0.2	3.2 ± 0.1	7.0 ± 0.1
Utorda coastal	3.0 ± 0.2	6.8 ± 0.1	2.8 ± 0.2	6.9 ± 0.2
Quelossim khazans	7.68 ± 0.1	5.0 ± 0.1	7.5 ± 0.1	5.3 ± 0.1
Velguem mining areas	0.5 ± 0.2	5.2 ± 0.2	0.48 ± 0.	4.9 ± 0.1

TABLE 2. Density of BGA in different habitats during the study period

Year	2006-2007 No. of BGA/ml x10^2		2007-2008 No. of BGA/ml x10^2		2008-2009 No. of BGA/ml x10^2	
Seasons	khariff	rabi	khariff	rabi	khariff	rabi
Group			Hinterland			
Heterocystous	640	610	620	600	510	560
Non-Heterocystous	470	400	430	440	440	480
Unicellular	480	500	510	480	440	440
			Coastal			
Heterocystous	540	560	530	550	600	550
Non-Heterocystous	540	540	530	500	530	540
Unicellular	440	470	460	500	530	540
			Khazans			
Heterocystous	500	470	450	460	420	390
Non-Heterocystous	430	450	440	440	460	470
Unicellular	350	380	360	390	340	400
			Mining areas			
Heterocystous	320	340	340	320	350	310
Non-Heterocystous	310	290	290	310	340	330
Unicellular	260	270	220	290	250	220

RESULT

The present study was undertaken to evaluate cyanobacterial diversity and density in diverse rice soil ecologies of Goa during the two growing seasons of khariff and rabi. The physicochemical environment of the sampling sites show variations in recordings of EC and pH (Table 1). The slightly alkaline pH of 7-7.3 as recorded in the hinterland paddy fields of Quepem with an EC of 3.5dsm^{-1} whereas coastal region of Utorda recorded a pH of 6.8 with a moderate EC of 3.0 dsm^{-1}. The other two sampling sites recorded acidic pH in the range of 5 to 6 with a high EC of 7.6 dsm^{-1} in Quelossim khazans and a low EC of 0.5 dsm^{-1}in Velguem mining area rice fields. The highest density of 640x10^2 algal cells/ml in khariff season of heteroystous forms in the hinterlands of Quepem was observed in the year 2006-2007 followed by coastal region of Utorda which recorded 540x10^2 algal cells/ml, followed by khazan lands with 500 x10^2 algal cells/ml and the least were recorded in mining areas 320 x10^2 algal cells/ml. But, however rabi season recorded comparatively less than khariff in hinterlands ($610x10^2$ cells/ml) and khazan lands ($470x10^2$ cells/ml) and comparatively more in the remaining two habitats. Overall the data indicates the predominance of heterocystous forms in all the 4 habitats followed by non-heterocystous and unicellular forms Song *et al*., (2005). In the present investigation three different diversity indices have been studied for the three groups of BGA in the four different habitats.

Hinterlands

Among the heterocystous forms, hinterlands recorded the highest density of $640x10^2$ cells/ml in khariff season of 2006-2007 and the least density of $510x10^2$ cells/ml in rabi season of 2008-2009. The non-heterocystous forms recorded the highest density of $480x10^2$ cells/ml in the rabi season of 2008-2009 and lowest density of $400x10^2$ cells/ml in the rabi season of 2006-2007. Among the unicellular forms, the highest density of $510x10^2$ cells/ml was recorded in the rabi season of 2006-2007 and the least density of $440x10^2$ cells/ml in khariff and rabi season of 2008-2009 (Table 2). The fields had a slightly alkaline pH of 7-7.3 with an EC of $3.5dsm^1$ (Table 1).

Shannon's diversity index for heterocystous forms ranged from 1.5 to 1.608 in the hinterlands with a minimum of 1.597 recorded in the khariff season of the year 2006-2007. Whereas the non-heterocystous and unicellular forms recorded Shannon's diversity index of more than 1.6 in both khariff as well as rabi season indicating considerable diversity. Simpson's diversity index for heterocystous forms ranged from 0.7949 to 0.7992 with the least diversity of 0.7949 in the khariff season of the year 2006-2007. Non-heterocystous forms recorded the highest Simpsons diversity index of 0.8 in the rabi season of 2008-2009, ever recorded for any BGA group in all the four habitats. Unicellular forms ranged in Simpson's diversity index from 0.7976 to 0.7995. Margaleff's diversity index ranged from 0.9618 to 1.017 for heterocystous forms with highest 1.017 recorded in the rabi season of the year 2008-2009. Whereas non-heterocystous and unicellular forms recoded above 1 in the range of 1.017 to 1.063. The highest value of Margaleff's diversity index of 1.603 was recorded for non-heterocystous forms in the khariff season of the year 2007-2008. Unicellular forms recorded the lowest Margaleff's index of 1.017 in the khariff season of the year 2007-2008 and the highest value of 1.057 was recorded in the khariff as well as rabi season of 2008-2009 (Table 3).

Coastal rice fields

Among the heterocystous forms, coastal rice fields recorded the highest density of 600 cells/ml in khariff season of 2008-2009 and the least density of 530 cells/ml in khariff season of 2007-2008. The non heterocystous forms recorded the highest density of 540 cells/ml in the khariff and rabi season of 2006-2007 and rabi season of 2008-2009 and lowest density of 500 cells/ml in the rabi season of 2007-2008. Among the unicellular forms, the highest density of 540 cells/ml was recorded in the rabi season of 2008-2009 and the least density of 440 cells/ml in khariff season of 2006-2007 (Table 2). Coastal region of Utorda recorded a pH of 6.8 with a moderate EC of 3.0 dsm^{-1} (Table 1).

Shannon's diversity index for heterocystous forms in coastal region ranges from 1.593 to 1.608. The lowest Shannon's diversity index of 1.593 for heterocystous forms was recorded in the rabi season of the year 2008-2009 followed by 1.596 in the rabi season of the year 2007-2008. The non-heterocystous forms recorded the lower of 1.598 in the rabi season of 2006-2007 and the unicellular forms in coastal rice fields recorded above 1.6 in all seasons during the study period. Simpson's diversity index for heterocystous forms ranged from 0.7966 to 0.799, the lowest of 0.7966 being recorded in the rabi season of the year 2006-2007 and the highest of 0.799 being recorded in the khariff season of both 2007-2008 and 2008-2009. Simpson's diversity index for non-heterocystous forms ranged from 0.7956 to 0.7992, the lowest of 0.7956 being recorded in the rabi season of the year 2006-2007 and the highest of 0.7992 were recorded in the rabi season of the year 2007-2008. Simpson's diversity index for unicellular forms ranged from 0.796 to 0.7992, the lowest of 0.796 being recorded in the rabi season of the year 2008-2009 and the highest was recorded in the rabi season of the year 2007-2008. Margaleff's diversity index ranged from 0.9937 to 1.007 for heterocystous forms with highest 1.007 recorded in the khariff season of the year 2007-2008 followed by 1.003 recorded in the khariff season of 2006-2007. Whereas non-heterocystous forms all recorded above 1 in the range of 1.003 to 1.022. The highest value of Margaleff's diversity index of 1.022 for non-heterocystous forms was recorded in the rabi season of the year 2007-2008. Unicellular forms recorded the Margaleff's diversity index ranging from 1.003 to 1.057. The lowest value of 1.003 was recorded in the rabi season of the year 2008-2009 and highest value of 1.057 was recorded in the khariff season of the year 2006-2007 (Table 3).

Khazan rice fields

Among the heterocystous forms, khazan rice fields recorded the highest density of 500 $x10^2$ cells/ml in khariff season of 2006-2007 and the least density of 390 $x10^2$ cells/ml in rabi season of 2008-2009. The non heterocystous forms recorded the highest density of $470x10^2$ cells/ml in the rabi season of 2008-2009 and lowest density of 430 $x10^2$ cells/ml in the khariff season of 2006-2007. Among the unicellular forms, the highest density of $400x10^2$ cells/ml was recorded in the rabi season of 2008-2009 and the least density of $340x10^2$ cells/ml in khariff season of 2008-2009 (Table 2). The khazans recorded acidic pH in the range of 5 to 6 with a high EC of 7.6 dsm^{-1} (Table 1).

Shannon's diversity index for heterocystous forms in khazan lands ranged from 1.604 to 1.608 during the study period. The lowest Shannon's diversity index of 1.604 for heterocystous forms was recorded in the khariff season of the year 2006-2007 followed by 1.605 in the rabi season of the year 2008-2009 and the highest of 1.608 was recorded in the khariff season of both 2006-2007 and 2008-2009. The non-heterocystous forms recorded the lowest Shannon's diversity index of 1.593 in the khariff season of 2006-2007 and the highest of 1.606 in the khariff seasons of both 2006-2007 and 2008-2009. Unicellular forms in khazan rice fields recorded in the range of 1.601 to 1.606 and hence showed values above 1.6 in all seasons during the study period indicating a moderately high and uniform diversity. Simpson's diversity index for heterocystous forms ranged from 0.7976 to 0.7995 whereas non-heterocystous forms ranged from 0.7939 to 0.799 and unicellular forms from 0.7986 to 0.799 during the study period. Margaleff's diversity index ranged from 1.022 to 1.092 for heterocystous forms with highest of 1.092 recorded in the rabi season for the year 2008-2009 followed by 1.07 recorded in the khariff season of 2008-2009. The lowest value of Margaleff's diversity index of 1.022 was recorded in the khariff season for the year 2006-2007. Whereas non-heterocystous forms recorded in the range of 1.039 to 1.063. The highest value of Margaleff's diversity index of 1.063 for non-heterocystous forms was recorded in the khariff season for the year 2006-2007 and the lowest value of Margaleff's diversity index of 1.039 was recorded in the rabi season for the year 2008-2009. Unicellular forms recorded the Margaleff's diversity index ranging from 1.1 to 1.134. The lowest value of 1.1 was recorded in the rabi season for the year 2006-2007 and highest value of 1.134 was recorded in the khariff season for the year 2008-2009 (Table 3).

Mining area rice fields of Velguem-Pale

Among the heterocystous forms, mining affected rice fields recorded the highest density of $340x10^2$ cells/ml in rabi season of 2006-2007 and khariff season of 2007-2008 and the least density of $310x10^2$ cells/ml in rabi season of 2008-2009. The non-heterocystous forms recorded the highest density of $340x10^2$ cells/ml in the khariff season of 2007-2008 and lowest density of $290x10^2$ cells/ml in the rabi season of 2006-2007 and khariff season of 2007-2008. Among the unicellular forms, the highest density of 290 cells/ml was recorded in the rabi season of 2007-2008 and the least density of $220x10^2$ cells/ml in khariff season of 2007-2008 and rabi season of 2008-2009 (Table 2). This site recorded acidic pH in the range of 5 to 6 with a low EC of 0.5 dsm^{-1} (Table 1). Shannon's diversity index for heterocystous forms in mining area rice fields ranges from 1.601 to 1.607 during the study period. The lowest Shannon's diversity index of 1.601 for heterocystous forms was recorded in the khariff season of the year 2008-2009 followed by 1.602 in the rabi season of the year 2008-2009 and the highest of 1.607 was recorded in the khariff season of both 2006-2007 and rabi season of 2007-2008. Whereas the non- heterocystous forms recorded values ranging from 1.597 to 1.608, the lowest Shannon's diversity index of 1.597 was recorded in the rabi season of 2007-2008 and the highest of 1.608 in the khariff seasons of both 2007-2008. Unicellular forms in mining area rice fields recorded in the range of 1.597 to 1.603 showing least diversity of 1.597 in the khariff season of 2008-2009 and maximum Shannon's diversity of 1.603 in the khariff season of the year 2007-2008. Simpson's diversity index for heterocystous forms range from 0.7976 to 0.7988 whereas non-heterocystous forms range from 0.7967 to 0.799 and unicellular forms range from 0.7929 to 0.798 during the study period. Margaleff's diversity index ranged from 1.125 to 1.165 for heterocystous forms with highest of 1.165 and the least of 1.125 both recorded in the rabi season and the khariff seasons respectively of the year 2008-2009. Whereas non-heterocystous forms recorded Margaleff's diversity index in the range of 1.134 to 1.188. The highest value of Margaleff's diversity index of 1.188 was recorded in the rabi season of 2007-2008 for non-heterocystous forms and the lowest value of Margaleff's diversity index of 1.134 was recorded in the khariff season of 2007-2008. Unicellular forms recorded the Margaleff's diversity index ranging from 1.188 to 1.294. The lowest value of 1.188 was recorded in the rabi season of the year 2007-2008 and highest value of 1.294 was recorded in the rabi season of the year 2008-2009.

DISCUSSION

Rice fields are temporary wetland ecosystems, with variable biodiversity and cyanobacteria are known to be an integral component of waterlogged rice fields. The rice field ecosystems with its optimum levels of light, water, temperature, humidity and nutrient availability provide a favourable environment for the luxuriant growth of cyanobacteria. The favourable balance of soil nitrogen of rice fields wherein rice can be grown on the same land even without any addition of fertilizers and without any reduction in yield, confirms to the significance of cyanobacterial nitrogen fixation (Venkatraman, 1972; Nayak *et al*., 2001; Nayak *et al*., 2004; Song *et al*., 2005). It is also a well known fact that besides contributing to soil nitrogen and improvement in yield of rice, cyanobacteria also produces agronomically significant changes in the physical, chemical and biological properties of soil and soil-water interface of rice fields (Mandal *et al*., 1998; Nayak *et al*., 2004). This may account for the higher abundance of cyanobacteria in paddy fields than in cultivated soils as reported under widely different climatic conditions of India (Mitra, 1951). In tropical rice fields, biological nitrogen fixation is mainly contributed by indigenous population of cyanobacteria or application of biofertilizers (algalization), which meets the nitrogen demand of the rice crop. Therefore efforts need to be focused towards enrichment of indigenous population of cyanobacteria, which are better adapted to the specific niche, through development of multiple inoculate preparations on regional basis. The present study was undertaken to evaluate cyanobacterial diversity and density in diverse rice soil ecologies of Goa during the two growing seasons of khariff and rabi.

Density data shows the highest density of $640x10^2$ cells/ml in khariff season of heteroystous forms in the hinterlands of Quepem in the year 2006-2007 followed by coastal region of Utorda which recorded $540x10^2$ cells/ml followed by khazan lands with $500x10^2$ cells/ml and the least were recorded in mining areas 320 $x10^2$ cells/ml. But however rabi season recorded comparatively less than khariff in hinterlands ($610x10^2$ cells/ml) and khazan lands ($470x10^2$ cells/ml) and comparatively more in the remaining two habitats. Overall the data indicates the predominance of heterocystous forms in all the 4 habitats followed by non-heterocystous and unicellular forms (Table 2). Similar results were obtained in a study where 166 cyanobactarial isolates were purified which included maximum heterocystous genera followed by non-heterocystous forms in diverse rice soil ecologies (Prassanna and Saswati, 2007). Earlier studies on cyanobacterial diversity of rice fields at the Indian Agricultural Research Institute have shown the predominance of heterocystous forms irrespective of chemical fertilizer/biofertilizers treatment and stage of crop growth (Nayak *et al*. 2001, 2004).

In the present study, paddy fields of hinterlands are richest in cyanobacterial density followed by coastal fields and khazans and least in mining areas. The physicochemical environment of the sampling sites show variations in recordings of EC and pH (Table 1). The slightly alkaline pH of 7-7.3 as recorded in the hinterland paddy fields of Quepem with an EC of 3.5dsm^{1} & coastal region of Utorda recorded a pH of 6.8 with a moderate EC of 3.0 dsm^{-1}. The other two sampling sites recorded acidic pH in the range of 5 to 6 with a high EC of 7.6 dsm^{-1} in Quelossim khazans and a low EC of 0.5 dsm^{-1}in Velguem mining area rice fields. Although cyanobacteria are ubiquitous in their distribution, it is well established that they prefer neutral to slightly alkaline pH. A study on biodiversity and seasonal variation of cyanobacterial strains in rice fields of Fujian China showed that cyanobacterial diversity in deeper soil fractions was higher than the upper soil fractions, and in addition the highest diversity was found in the middle of growth season and the lowest after harvest (Song *et al*., 2005).

Shannon's diversity indices in all the habitats of all groups of BGA were in the range 1.5-1.6. The highest Shannon's diversity index of 1.608 was recorded in khariff season during the study period 2008-2009 in coastal and khazan lands for heterocystous forms. Whereas lowest Shannon's diversity index of 1.587 was recorded in khariff season during the study period 2008-2009 in mining area rice fields for unicellular forms.

Simpson's diversity indices in all the habitats of all groups of BGA range from 0.79-0.80. The highest Simpson's diversity index of 0.80 was recorded during the study period 2008-2009 in rabi season for non-heterocystous in the Quepem hinterland, whereas lowest Simpson's diversity index of 0.790 was recorded in khariff season during the study period 2008-2009 in mining area rice fields for unicellular forms (Table 3). In a similar study Shannon's diversity index was indicative of extensive diversity of cyanobacteria within the rhizosphere of rice cultivars. Simpson's diversity index (1-D) which takes into accounts both richness and evenness also showed significant values (Prassanna *et al*., 2009).

The Margalef's diversity indices in all the habitats of all three groups of BGA were in the range of 0.9-1.2. The highest Margalef's diversity index of 1.294 was recorded during the khariff season of study period 2007-2008 and rabi season of 2008-2009 for unicellular forms in mining area rice fields, whereas lowest Margalef's diversity index of 0.9618 was recorded in khariff season during the study period 2006-2007 in hinterlands rice fields for heterocystous forms in khariff season (Table 3). The present study indicates a moderately rich but variable diversity of BGA in Goan rice fields. It is evident from the results that though the count of heterocystous BGA was the highest in all rice fields but the diversities of all groups are moderately high in all the four habitats. Thus the present investigation throws light on the density and diversities of BGA in Goan rice fields especially with regard to the indigenous species which could help in development of niche specific inoculates for Goan rice fields.

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TABLE 3. Comparative diversity indices of BGA in different habitats

Year of study	2006-2007						2007-2008						2008-2009					
Season	Khariff			Rabi			Khariff			Rabi			Khariff			Rabi		
Diversity indices	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Hetererocystous																		
Hinterlands	1.597	0.7949	0.9618	1.608	0.7992	0.973	1.606	0.799	0.9692	1.602	0.7972	0.977	1.601	0.797	1.017	1.604	0.798	0.9937
Coastal	1.605	0.7984	1.003	1.601	0.7966	0.9937	1.607	0.799	1.007	1.596	0.7947	0.9982	1.608	0.799	0.977	1.593	0.793	0.9982
Khazans	1.604	0.7976	1.022	1.608	0.7995	1.039	1.607	0.799	1.051	1.606	0.7987	1.045	1.608	0.799	1.07	1.605	0.798	1.092
Mining areas	1.607	0.7988	1.154	1.603	0.7976	1.134	1.603	0.798	1.134	1.607	0.7988	1.154	1.601	0.797	1.125	1.602	0.797	1.165
Non-heterocystous																		
Hinterlands	1.606	0.7986	1.039	1.6	0.7962	1.084	1.605	0.798	1.063	1.603	0.7975	1.057	1.606	0.799	1.057	1.608	0.8	1.033
Coastal	1.605	0.7984	1.003	1.598	0.7956	1.003	1.605	0.798	1.007	1.607	0.7992	1.022	1.603	0.797	1.007	1.6	0.796	1.003
Khazans	1.593	0.7939	1.063	1.602	0.797	1.051	1.606	0.799	1.057	1.6	0.7965	1.057	1.606	0.799	1.045	1.604	0.798	1.039
Mining areas	1.602	0.7971	1.165	1.601	0.7967	1.188	1.601	0.797	1.188	1.597	0.795	1.165	1.608	0.799	1.134	1.607	0.799	1.144
Unicellular																		
Hinterlands	1.606	0.7986	1.033	1.604	0.7976	1.022	1.603	0.797	1.017	1.608	0.7995	1.033	1.606	0.799	1.057	1.606	0.799	1.057
Coastal	1.606	0.7986	1.057	1.606	0.7986	1.039	1.606	0.799	1.045	1.607	0.7992	1.022	1.603	0.797	1.007	1.6	0.796	1.003
Khazans	1.601	0.7967	1.125	1.607	0.7992	1.1	1.604	0.798	1.116	1.605	0.7982	1.092	1.603	0.798	1.134	1.606	0.799	1.084
Mining areas	1.599	0.7959	1.228	1.592	0.7929	1.214	1.603	0.798	1.294	1.601	0.7967	1.188	1.587	0.79	1.243	1.603	0.798	1.294

1 – Shannon diversity index 2 – Simpson diversity index 3 – Margalef diversity index